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THE REACTION OF TRIALKYLVINYLBORATES WITH ALDEHYDES AS APPLIED TO SYNTHESES OF 1,3-ALKANEDIOLS, 1-CHLORO-3-HEPTANOL AND A CYCLOPROPANE DERIVATIVE

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Abstract—Treatment of R'CHO with $Li[R_3BCH{=}CH_2]$ gives an adduct which is believed to be $R_2BCHR{-}CH_2{-}CH(OLi)R'$ (2) or its borate form (3). Oxidation of the adducts with alkaline hydrogen peroxide gives *ca.* 1:1 mixture of diastereomeric 1,3-alkanediols in good yields. On the other hand, the reaction of $BrMg[R_3BCH{=}CH_2]$ with R'CHO affords less satisfactory results. Successive treatment of 2 (R = n-Bu, R' = H) with PCl_5 and alkaline H_2O_2 gives $HOCHBu{-}CH_2{-}CH_2Cl$ (6). Treatment of $Et_2BCHEt{-}CH_2{-}CHCl{-}Ph$ with NaOH aq produces 1-ethyl-2-phenylcyclopropane 7.

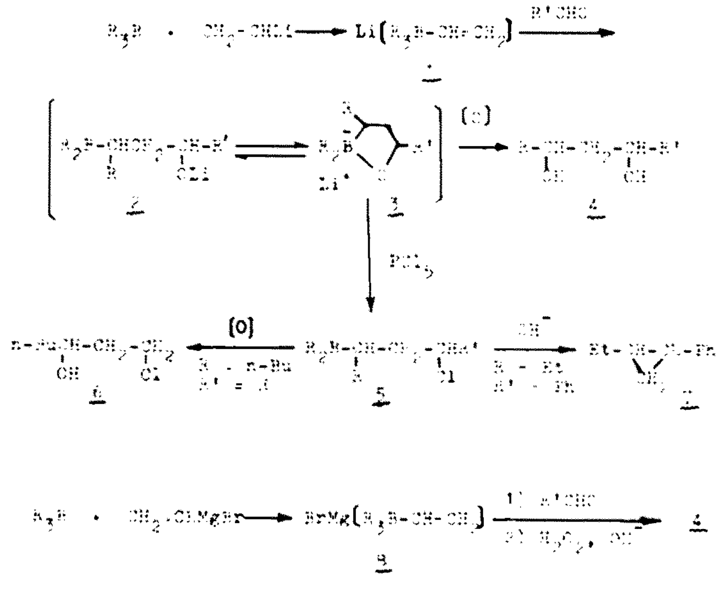
Boron ate complexes having sp or sp^2 carbon next to boron have been known as versatile nucleophiles[1] leading to a wide variety of organic compounds including acetylenes,[2] olefins,[3] alcohols,[4] ketones,[5] and polyfunctional compounds.[6] More recently, the reaction of lithium trialkylvinylborates (1) with oxiranes has been reported to afford 1,4-alkanediols in excellent yields and opened a novel approach to cyclopentenone synthesis.[7] This paper describes a simple synthesis of another kind of glycols, 1,3-alkanediols, by the reaction of trialkylvinylborates with aldehydes via the adducts 2. Transformations of 2 into a 1-chloro-3-alkanol and a cyclopropane are also described.[8]

Reaction of lithium tributylvinylborate (1, R = n-Bu) with isobutyraldehyde gave an adduct 2 (R = n-Bu, R' = i-Pr) which was neither isolated nor detected spectroscopically but estimated by the analogy to the reaction of lithium trialkylvinylborates (1) with oxiranes.[7] Oxidative workup of the reaction mixture gave 2-methyl-3,5-nonanediol (**4c**, R = n-Bu, R' = i-Pr) in 74% yield. GLC analysis of the bistrimethylsilyl ether of the diol indicated that this was a mixture of two diastereomers (nearly 1:1). Combinations of the substituents (R and R') and alkanediols prepared in this way are listed in Table 1.

Reactions of the borates with electrophiles have usually been carried out under anhydrous condition because of sensitivity of the borates towards water.[9] We wish to point out that formalin, in place of paraformaldehyde, was capable of affording a 1,3-alkanediol in lower yield as compared with paraformaldehyde case.

We have found that vinylmagnesium bromide can be used much more conveniently than vinyllitium for the preparation of boron ate complexes and the subsequent reaction with oxiranes.[10] In contrast, the reaction of bromomagnesium trialkylvinylborates 8 with aldehydes gave less satisfactory yields of 1,3-alkanediols as shown in Table 1.

Transformation of the intermediates 2 or 3 into a



Scheme 1.

Table 1. Alkanediols R–CH(OH)CH$_2$CH(OH)–R′ by reaction of M[R$_3$BCH=CH$_2$] with R′CHO

	R	R′	Yield (%)[a] M = Li (= MgBr)	Diastereomer[b,c] Ratio
4a	Et	Ph	78	51:49
b	n-Bu	H (CH$_2$O)$_n$	80 (31)	——
b	n-Bu	H (formalin)[d]	49	——
c	n-Bu	i-Pr	74 (25)	49:51 (50:50)
d	n-Bu	Ph	72 (70)	49:51 (48:52)
e	n-Bu	CH$_3$CH=CH-	48	36:64
f	i-Pr	H (CH$_2$O)$_n$	74 (32)	——
g	i-Pr	CH$_3$	52	50:50
h	i-Pr	i-Pr	73 (23)	56:44 (53:47)
i	i-Pr	Ph	65 (56)	50:50 (49:51)
j	i-Pr	CH$_3$CH=CH-	28	59:41

[a] Based on trialkylborane. [b] All diastereomer ratios have been determined by GLC analysis of the respective bistrimethylsilyl ethers. The configuration of each isomer could not be determined. [c] Ratios in parentheses refer to the bromomagnesium borate reaction. [d] Commercial product containing 37% formaldehyde in water.

1-chloro-3-alkanol or a cyclopropane via dialkyl-(3-chloroalkyl)borane **5** was illustrated in the following way.[11] The borate **3** (R = n-Bu, R′ = H) was treated with phosphorus pentachloride[12] and oxidative workup afforded 1-chloro-3-heptanol **6** in 53% yield. On the other hand, treatment of **5** (R = Et, R′ = Ph) with aqueous alkali gave 1-ethyl-2-phenylcyclopropane **7** (50:50 mixture of *cis* and *trans* isomers) in 35% overall yield.[13]

EXPERIMENTAL

GLC was performed on a Shimadzu GC-4BPT with 3 m × 3 mm glass column packed with 20% PEG and 20% HVSG on Chromosorb W-AW (80–100 mesh). PMR spectra were taken on a Varian EM-360 or on a JEOL JNM-PMX60 spectrometer in CDCl$_3$ or CCl$_4$ soln with Me$_4$Si as an internal standard. IR spectra were recorded on a Shimadzu IR-27G grating spectrometer and mass spectra on a Hitachi RMU-6L machine with a chamber voltage of 70 eV. Microanalyses were performed at the Elemental Analyses Centre of Kyoto University.

Vinyllithium[14] was prepared by transmetallation of tetravinyltin[15] with butyllithium.[16] Acetaldehyde, isobutyraldehyde, benzaldehyde and crotonaldehyde were freshly distilled before use. Paraformaldehyde was dried over phosphorus pentoxide under reduced pressure for 2 days.

Preparation of 1,3-glycols by the reaction of Li[R$_3$BCH=CH$_2$] *with* R′CHO

A general procedure. To a soln of vinyllithium (5.0 mmol, 0.67 M ethereal soln) was added trialkylborane (5.0 mmol, neat) at 0° under argon atmosphere. After 30 min stirring at room temp. the mixture was treated with aldehyde (5.5 mmol) at 0° and stirred at room temp. to 40–45° for 13–45 hr. After dilution with ether, the mixture was oxidized with 3 N NaOH (3 ml) and 30% H$_2$O$_2$ (4 ml) at room temp. for 1 hr. Extraction with ether followed by washing, drying and distillation afforded the diol.

The diols obtained were analyzed on GLC as bistrimethylsilyl ether. The structure of diastereomers was not assigned, but the ratio was described according to an elution order on GLC. IR and PMR spectra were taken for a diastereomeric mixture and mass spectra were recorded as bistrimethylsilyl ether for each first eluted diastereomer on GLC.

The data of individual compounds were given in the following order: the scale of preparative experiment in mmol, reaction temp. and time together with b.p. and spectral data of the product.

1-*Phenyl*-1,3-*pentanediol* (**4a**). 5 mmol, 40–45° (bath temp.), 14 hr. B.p. 170–180°/4 mm, IR (neat): 3310, 3050, 3020, 1604, 1495, 1122, 1062, 1023, 756, 700 cm^{-1}, PMR (CDCl$_3$): δ 0.88 (t, J = 7 Hz, 3H), 1.2–1.6 (m, 2H), 1.6–2.0 (m, 2H), 3.5–4.2 (broad s, 2H, OH), 3.5–4.0 (m, 1H), 4.7–5.2 (m, 1H), 7.32 (s, 5H), MS of bistrimethylsilyl ether: *m/e* (rel. %) 309 (M-15, 0.1), 234 (20), 205 (20), 180 (22), 179 (100), 147 (28), 131 (18), 75 (17), 73 (71). (Found: C, 73.48, H, 9.17. Calc. for $C_{11}H_{16}O_2$: C, 73.30, H, 8.95%).

1,3-*Heptanediol* (**4d**)—*reaction with paraformaldehyde.* 3 mmol, room temp. 15 hr. B.p. 135–145° (bath temp.)/18 mm (lit.[17] 140–144°/25 mm), IR (neat): 3330, 1052 cm^{-1}, PMR (CDCl$_3$): δ 0.93 (t, J = 6 Hz, 3H), 1.1–1.8 (m, 8H), 3.3–3.6 (broad s, 2H, OH), 3.6–4.0 (m, 3H), MS of bistrimethylsilyl ether: *m/e* (rel. %) 261 (M-15, 1), 233 (5), 219 (30), 159 (46), 147 (40), 129 (16), 103 (90), 75 (26), 73 (100). *Reaction with formalin* (37%). 3 mmol, room temp., 15 hr.[18]

2-*Methyl*-3,5-*nonanediol* (**4c**). 5 mmol, 40–45° (bath temp.), 13 hr. B.p. 100–110° (bath temp.)/2 mm, IR (neat): 3340, 1051, 849 cm^{-1}, PMR (CDCl$_3$): δ 0.70–1.1 (m, 9H), 1.1–2.0 (m, 9H), 3.35 (s, 2H, OH), 3.4–4.0 (m, 2H), MS of bistrimethylsilyl ether: *m/e* (rel. %) 303 (M-15, 0.1), 275 (2), 160 (14), 159 (100), 147 (13), 145 (40), 75 (18), 73 (63), 69 (12). (Found: C, 69.20; H, 13.02). Calc. for $C_{10}H_{22}O_2$: C, 68.91; H, 12.71%).

1-*Phenyl*-1,3-*heptanediol* (**4d**). 3 mmol, room temp., 15 hr. B.p. 105–115° (bath temp.)/0.08 mm, IR (neat): 3330, 3060, 3030, 1605, 1495, 1128, 1050, 757, 700 cm^{-1}, PMR (CDCl$_3$): δ 0.88 (t, J = 6 Hz, 3H), 1.1–1.6 (m, 6H), 1.6–2.0 (m, 2H), 3.3–3.6 (broad s, 2H, OH), 3.6–4.1 (m, 1H), 4.7–5.1 (m, 1H), 7.29 (s, 5H), MS of bistrimethylsilyl ether: *m/e* (rel. %) 352 (M^+, 2), 262 (18), 205 (16), 180 (23), 179 (100), 159 (19), 147 (20), 75 (20), 73 (85). (Found: C, 74.86; H, 9.88. Calc. for $C_{11}H_{20}O_2$: C, 74.96; H, 9.68%).

2(*E*)-*Decene*-4,6-*diol* (**4e**). 3 mmol, room temp., 15 hr. B.p. 120–130° (bath temp.)/3 mm. IR (neat): 3340, 1039, 966 cm^{-1}, PMR ($CDCl_3$): δ 0.92 (t, J – 6 Hz, 3H), 1.1–1.8 (m, 11H), 2.6–3.1 (broad s, 2H, O$\underline{H}$), 3.6–4.1 (m, 1H), 4.1–4.6 (m, 1H), 5.5–5.8 (m, 2H), MS of bistrimethylsily ether: *m/e* (rel. %) 301 (M-15, 0.1), 259 (1), 233 (5), 211 (7), 169 (18), 159 (39), 147 (28), 144 (14), 143 (88), 75 (30), 73 (100). (Found: C, 69.28; H, 11.94. Calc. for $C_{10}H_{20}O_2$: C, 69.72; H, 11.70%).

4-*Methyl*-1,3-*pentanediol* (**4f**). 5 mmol, 40–45° (bath temp.), 14 hr. B.p. 160–170° (bath temp.)/26 mm (lit.[19] 130° (bath temp.)/10 mm). IR (neat): 3340, 1389, 1372, 1052 cm^{-1}, PMR ($CDCl_3$): δ 0.94 (d, J = 6 Hz, 6H), 1.5–2.0 (m, 3H), 3.1–3.5 (broad s, 2H, O$\underline{H}$), 3.63 (q, J = 6 Hz, 1H), 3.88 (t, J = 6 Hz, 2H), MS of bistrimethylsilyl ether: *m/e* (rel. %) 262 (M^+, 0.1), 247 (0.3), 219 (46), 147 (23), 145 (20), 103 (100), 75 (17), 73 (77).

5-*Methyl*-2,4-*hexanediol* (**4g**). 3 mmol, room temp., 45 hr. B.p. 105–115° (bath temp.)/10 mm (lit.[20] 75°/1 mm), IR (neat): 3330, 1118, 1060 cm^{-1}, PMR ($CDCl_3$): δ 0.92 (d, J = 6 Hz, 6H), 1.23 and 1.25(2d, J = 6 Hz, 3H), 1.4–2.0 (m, 3H), 3.4–4.4 (m, 4H, C$\underline{H}$–O, O$\underline{H}$), MS of bistrimethylsilyl ether: *m/e* (rel. %) 276 (M^+, 0.2), 233 (7), 159 (30), 147 (30), 143 (17), 130 (13), 118 (13), 117 (100), 75 (21), 73 (67).

2,6-*Dimethyl*-3,5-*heptanediol* (**4h**). 5 mmol, 40–45° (bath temp.), 14 hr. B.p. 95–105° (bath temp.)/5 mm. The diol crystallized on standing, m.p. 65–67° (lit.[17] 68°, 30% erythro and 70% threo). IR (neat): 3360, 1386, 1369, 1048 cm^{-1}, PMR ($CDCl_3$): δ 0.92 (d, J – 6 Hz, 12H), 1.1–2.0 (m, 4H), 3.2–3.7 (broad s, 2H, O$\underline{H}$), 3.5–3.8 (m, 2H), MS of bistrimethylsilyl ether: *m/e* (rel. %) 289 (M-15, 0.1), 261 (1), 147 (11), 146 (13), 145 (100), 75 (14), 73 (46).

1-*Phenyl*-4-*methyl*-1,3-*pentanediol* (**4i**). 5 mmol, 40–45° (bath temp.), 14 hr. B.p. 90-100° (bath temp.)/0.06 mm. IR (neat): 3340, 3060, 3030, 1605, 1495, 1013, 757, 700 cm^{-1}; PMR ($CDCl_3$): δ 0.89 (d, J 7 Hz, 6H), 1.1–2.0 (m, 3H), 2.8–3.2 (broad s, 2H, O$\underline{H}$), 3.4–3.9 (m, 1H), 4.6–5.1 (m, 1H), 7.30 (s, 5H), MS of bistrimethylsilyl ether: *m/e* (rel. %) 248 (M-90, 8), 205 (10), 180 (20), 179 (100), 147 (14), 145 (11), 75 (36), 73 (76). (Found: C, 74.26; H, 9.55. Calc. for $C_{12}H_{18}O_2$: C, 74.19; H, 9.34%).

7-*Methyl*-2(*E*)-*octene*-4,6-*diol* (**4j**). 5 mmol, 40–45° (bath temp.), 14 hr. B.p. 105–115° (bath temp.)/5 mm, IR (neat): 3330, 1048, 965 cm^{-1}, PMR ($CDCl_3$): δ 0.92 (d, J = 6 Hz, 6H), 1.1–2.0 (m, 6H), 2.9–3.4 (broad s, 2H, O$\underline{H}$), 3.4–3.9 (m, 1H), 4.0–4.5 (m, 1H), 5.5–5.8 (m, 2H), MS of bistrimethylsilyl ether: *m/e* (rel. %) 259 (M-43, 1), 197 (9), 187 (9), 147 (14), 145 (28), 144 (15), 143 (100), 75 (27), 73 (79). (Found: C, 68.06; H, 11.40. Calc. for $C_9H_{18}O_2$: C, 68.31; H, 11.47%).

1-*Chloro*-3-*heptanol* (**6**). To a stirred soln of lithium tributylvinylborate (5.0 mmol) in ether was added paraformaldehyde (165 mg, 5.5 mmol) in one portion at room temp. After 14 hr at 40–45° (bath temp.), the mixture was cooled with ice-salt bath, and added with 10 ml of dry ether and PCl_5 (1.56 g, 7.5 mmol). Immediately, white ppt was formed and the whole was stirred at 0° for 4 hr and then at 40° for 1.5 hr. Usual workup, extraction and distillation gave 9 (0.40 g, 53% yield), b.p. 140–150° (bath temp.)/5 mm (lit.[21] 100–105°/3 mm). IR (neat): 3340, 1040 cm^{-1}; PMR ($CDCl_3$): δ 0.92 (t, J – 6 Hz, 3H), 1.1–1.7 (m, 7H, three methylenes and O$\underline{H}$), 1.85 (q, J – 7 Hz, 2H), 3.4–4.0 (m, 3H); MS of trimethylsilyl ether: *m/e* (rel. %) 209 (M-15, 1), 207 (M-15, 3), 181 (3), 179 (10), 167 (20), 165 (54), 159 (30), 115 (39), 75 (55), 73 (100), 69 (39), 55 (40).

1-*Ethyl*-2-*phenylcyclopropane* (**7**). After treatment of lithium triethylvinylborate (3.0 mmol) with benzaldehyde (0.35 g, 3.3 mmol) in ether at 40–45° (bath temp.) for 14 hr, the resulting mixture was cooled with ice-salt bath and added with 10 ml of dry ether and PCl_5 (0.94 g, 4.5 mmol). Stirring was continued for 4 hr at 0° and 1.5 hr at 40–45°. The mixture was treated cautiously with 10 ml of 3 N NaOH at 0° and stirred for 1 hr at room temp. Cyclopropane 7 was obtained[22] in 35% yield by GLC analysis (n-decane as an internal standard), E:Z 50:50. IR (neat): 3060, 3030, 1606, 1498, 1454, 1028, 768, 697 cm^{-1}; PMR (CCl_4): δ 0.5–1.6 (m, 9H), 6.7–7.4 (m, 5H); MS: *m/e* (rel. %) 146 (M^+, 37), 117 (100), 115 (27), 104 (59), 91 (36), 78 (10), 77 (10).

Preparation of 1,3-*glycols by the reaction of* $BrMg[R_3BCH{=}CH_2]$ *with* R'CHO.

A general procedure. A soln of vinylmagnesium bromide (6.0 mmol, 0.80 M tetrahydrofuran soln) was treated with trialkylborane (5.0 mmol) at 0° and the mixture was stirred at 0° for 1 hr and at room temp. for 1 hr. Aldehyde (5.5 mmol) was added to the resulting soln at 0° and the mixture was stirred at 0° for 2 hr and at room temp. for 14 hr. Oxidative workup with alkaline H_2O_2 followed by extraction and column chromatography (silica gel, hexane-ethyl acetate 2:1) gave the diol.

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